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AN EVALUATION OF A SUGGESTED METHOD FOR MEASURING THE EFFECTIVENESS OF THE UTILIZATION OF TECHNICALLY TRAINED PERSONNEL

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Submitted in partial fulfillment
of the requirements for the
degree of

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IN
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ABSTRACT

A test based on the Operations Analysis Curriculum at the United States Naval Postgraduate School was administered to 104 Naval Officers. All examinees were graduates or students of the Operations Analysis Curriculum and/or officers holding Operations Anslysts billets in the Navy. The sub-sample, 34 examinees, consisting of officers holding Operations Analysts billets and/or Operations Analysis graduates was not sufficient to make adequate statistical determination of the measure of effectiveness proposed in a suggested methodology. The data gathered did crudely support hypothesized learning and forgetting curves and suggested that the effectiveness of Operations Analysis graduates assigned directly to Operations Analysts billets immediately after graduation is much enhanced compared to graduates who are returned first to fleet operational billets. The effectiveness of Operations Analysis trained officers in Operational Analyst billets was shown to be quantitatively and subjectively <u>significantly</u> superior to those with no formal Operations Analysis training. These results indicate that Naval assignment policies should be reviewed in hopes of assigning more Operations Analysis trained officers (consistent with other requirements) to these

billets. Further investigation of the results of the test vehicle and other statistics common to Operations Analysis graduates yielded a feasible procedure with which to augment the screening of prospective Operations Analysis students. Final Quality Point Rating, an acceptable measure of performance, had a .614 correlation with four readily available statistics.

This evaluation suggests that further study in this area has great promise in yielding useful measures of effectiveness for all personnel filling billets requiring post-graduate education, provided a more effective method is employed to insure completion of the required test instrument(s).

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CHAPTER I

INTRODUCTION

In May of 1964 Commander P. D. Roman, and Lieutenant Commanders K. D. Russell and J. M. Dunlop posed a highly interesting and promising methodology designed to evaluate the effectiveness of the utilization of technically trained personnel within the Navy. [11] The personnel involved in this suggested Methodology were Naval Officers who have received postgraduate education. The main motivation for this proposed model was the fact that no previous quantitative study had been made to determine if a better balance of career duty assignments should be devised which would allow officers to attain the operational knowledge and experience requisite to Military Command and simultaneously approach maximum effective use of their technical skills (sub-specialties). Because the acquisition of technical skills is costly, as well as necessary, finding an optimal procedure to utilize these skills, consistent with other requisites, is virtually a "must." The pure rationality of cost-effectiveness alone supports this supposition.

Commander Roman, et. al., constructed a test instrument modeled on the Operations Analysis curriculum at USNPGS

which would, hopefully, measure the native ability and technical knowledge of Naval Officers who are holding Operations Analysis billets and/or graduates of the Operations Analysis Curriculum. It was their hypothesis that by categorizing these officers into several distinct groups the statistical results of their performance on this test would lead to a more efficient system of career planning for these officers. If this procedure proved successful for the Operations Analysis sub-specialty, it would obviously have applications for all officers who are technically trained. The authors of the referenced methodology have presented an admirable treatise on the need for the execution of such a quantitative study.

In September of 1964 the authors of this paper mimeographed the test instrument and distributed it to officers holding Operations Analysis "P" coded billets and/or graduates of the Operations Analysis Curriculum at USNPGS. A total of 34 returns from a population of 197 officers was realized. In January of 1965 the test was also administered to 36 second year Operations Analysis students at USNPGS scheduled to graduate in May 1965. In November of 1964, 34 first year Operations Analysis students completed the aptitude portion of the test vehicle.

The purpose of this paper is three-fold:

I. To determine the adequacy of the test as a measuring instrument, i.e., does it measure what it is supposed to measure?

II. To carry out, where possible, the statistical procedures suggested by Commander Roman, et. al., and analyse their usefulness and/or implications.

III. To analyse the results of a multiple linear regression analysis performed on the CDC 1604 Computer to develop a statistical means to augment selection procedures for input to the Operations Anslysis Curriculum.

The following chapter details the analysis of the data for each of these purposes.

CHAPTER II

THE ANALYSIS

I. Determination of the adequacy of the test instrument.

The test instrument used in this study consists of a background questionaire and three test parts. The questionaire is designed to obtain the examinee's educational background, a history of his duty assignments, a listing of graduate and undergraduate courses completed and the examinees opinions' as to what courses he is lacking that are required in his billet. The main purpose of this part of the test is to stratify the examinee according to educational background. The other information gained will provide further refinement of this stratification. The adequacy of this questionaire is <u>purely</u> subjective. The authors feel that the information provided by the questionaire will allow assignment of testees to logical categories of interest to this study.

Part I of this test is an aptitude test designed to provide a measure of the examinee's ability in problem solving, the only major factor accepted as effecting current measures of intelligence.[1] This test was constructed, from investigations

[1] Editorial. Federal Education, You're in the Classroom Now. Time, 83, 3, January 17, 1964: 72

[illegible]

of aptitudes of high level personnel, under the direction of Dr. J. P. Guilford at the University of Southern California, Los Angeles. [1,6,9] The authors will assume that the results of this exhaustive and authoritative study has led to the formulation of an excellent test to measure native ability. It follows that the results of this test will allow examinees to be rated according to inherent abilities. This stratification, coupled with background areas, will provide an excellent means for comparison of technical skills in the selected categories.

Part II of the test deals strictly with the retention of fundamental concepts of the basic courses within the Operations Analysis Curriculum: namely, Advanced Calculus, Linear Algebra and Probability theory. This test was formulated from suggestions of Professors of the Mathematics, Physics and Operations Analysis Departments of USNPGS. It is indeed a moot question as to whether or not a good working knowledge of these courses measures, with any degree of accuracy, the ability or success of an individual as an Operations Analyst. There can be little doubt, however, that proficiency in these fields does reflect <u>some</u> measure of the examinees technical abilities. Beacuse we are once again caught in a subjective (or qualitative) area, at this point we will assume that the combined opinions of these recognized

educators provides a good cross section of the technical knowledge required of an effective Operations Analyst, and the results of Part II of this test will yield, at least, a relative measure among the groups of officers of their abilities as Operations Analysts. Relative performance is, after all, a very important aspect in our real world and this relative performance is in essence one major objective of this study.

Part III is a practical test designed to evaluate the examinees' ability to recognize the applicability of a class of methods to specific problems. The situations presented in these problems do not have clean-cut answers, but are designed to determine how familiar an examinee is with an "accepted or proven" Methodology as related to well-known Operations Analysis problems. The answers to the situations posed are nothing more than a mean combination of opinions expressed by noted analysts and professors at USNPGS. Once again we are using the general reasoning of the preceding paragraph in stating that this portion of the test will display a relative measure of how familiar an examinee is with the "accepted" tactics of Operations Analysis.

Thus far we have been concerned with the question of whether the test will measure what we want it to measure.

Is it a valid indication of the technical abilities we are trying to measure? To this point we have tried to answer these questions in the affirmative by the use of subjective reasoning. This procedure is necessary because the determination of test validity does not readily or easily lend itself to meaningful quantitative analysis.[2] Despite this dilemma, certain mathematical techniques do allow a degree of quantitative determination of adequacy to be calculated. The entire question of determining the adequacy of this test could be measured by two broad criteria: VALIDITY and RELIABILITY. Reliability is defined as a measure of how faithfully the test allows the examinee to display the true percentage of the questions presented in the test to which he actually knows the answers. A mathematical presentation of this reliability follows.

Doctor J. P. Guilford has developed a mathematical model to evaluate the reliability of any test. Because the entire development is extremely lengthy we shall present only the basic assumptions and final forms of the reliability equations.[3]

[2]Guilford, J. P. Psychometric Methods, McGraw Hill Co., New York, 1954: 36

[3]Ibid: 344-409

The effects of these variations have been reduced as much as possible by the use of an a priori weighting of raw total scores.

$$S = \frac{R(K-1) - W}{K}, \quad (1)$$

where:
- S = Adjusted Score,
- R = Number of Right Answers,
- W = Number of Wrong Answers,
- K = Number of Alternate Responses to each item.

This method of scoring is designed to nullify the small but not necessarily minute possibility that the examinee may guess the correct answer.

Doctor Guilford has postulated that, in theory, a regression equation could be calculated between observed scores and the true score (exactly how many questions the student knows the answers to) as depicted in Figure 1. In the development of this theory Dr. Guilford postulated that in any academic area a test of infinite length would be necessary to completely describe an examinee's knowledge of the subject. In like manner the authors have denoted true score by the symbol ∞.

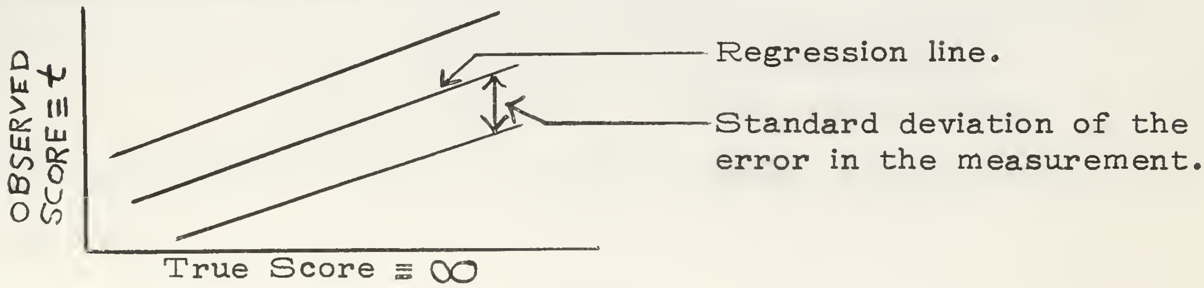


FIGURE 1

The following assumptions were used in the mathematical development:

I M_e $\equiv$ Mean error = 0.

II $r_{\infty,e}$ $\equiv$ Correlation of true and error scores = 0.

III r_{e_1,e_2} $\equiv$ Error score correlation in any two forms of the same test = 0.

IV Distribution of errors is normal.

It then follows that:

$$M_{\infty} = M_t + M_e = M_t$$

and

$$\sigma_{\infty} = \sigma_t + \sigma_e,$$ where σ_i = variance of i.

This leads to the logical definition of reliability of a test as the proportion of true variance in obtained test scores

or (2) $$r_{tt} = \frac{\sigma_{\infty}^2}{\sigma_t^2},$$

where:
r_{tt} $\equiv$ Test reliability, $0 \leq r_{tt} \leq 1$,
σ_{∞}^2 $\equiv$ True variance of test scores
σ_t^2 $\equiv$ Observed variance of test scores.

Because of the difficulty in obtaining σ_{∞}^2 equation (2) has been reduced (closely approximated) as follows:

(3) $$r_{tt} = 1 - \frac{\sigma_d^2}{\sigma_t^2},$$

where:
d $\equiv$ Difference between the scores on even items and odd items on the test,
σ_d^2 $\equiv$ Variance of these differences,
σ_t^2 $\equiv$ Variance of obtained total scores.

The variables in equation (3) can be readily calculated for any test.

A final consideration must be made in view of the fact that the test in question was timed and therefore speeded to some extent. Speed does detract from performance which we do not want reflected in reliability. The final form of this reliability equation is

(4) $$r_M = r_{tt} - \frac{\bar{u}}{\sigma_{te}^2},$$

where: $r_M \equiv$ Reliability of slightly speeded test,

$r_{tt} \equiv$ as before,

$\bar{u} \equiv$ mean number of unattempted items,

$\sigma_{te}^2 \equiv$ variance of total test error scores.

Equation (4) is a close approximation to true reliability, as previously defined, of a speeded test provided that:

$$\frac{\bar{u}}{\sigma_{te}^2} \leq 0.3$$

and

$$\frac{\sigma_u}{\sigma_w} \leq 1.3,$$

where: $\sigma_u \equiv$ Standard deviation of unattempted test items,

$\sigma_w \equiv$ Standard deviation of test items answered incorrectly.

As suggested by Commander Roman, et. al., examinees were placed in the following categories:

(1) USNPGS Students nearing completion of their final year of the curriculum.

(1A) USNPGS Students in second term of first year of Operations Analysis Curriculum.

(2A) Graduates who have been assigned (and are in) directly to Operations Analysis billets.

(2B) Graduates who have never been associated with Operations Analysis billets.

(2C) Graduates who have completed a direct assignment in Operations Analysis billets and are now in unassociated activities.

(2D) Graduates who were not immediately assigned Operations Analyst billets but are now serving in that capacity.

(3) Non-Graduates who are presently serving in Operations Analyst billets.

Clearly all examinees involved in this study fall into one and only one of these categories. The chosen method of attack is to compare various categories by means of forgetting, learning and re-learning curves in hopes of deducing a useful measure of effectiveness. As a common basic for comparison, all examinees were stratified by comparing their results of Part I (Inherent Abilities) with the mean score of Part I for Category I. This procedure is logical because present students should be more familiar with the basic fundamentals of the courses test Parts II and III are concerned with.

To be specific, a ratio of an individual's score on Part I to the mean score of Category I on Part I was multiplied by the scores on Part II and III and this figure compared to the same mean score attained on Parts II and III by Category I.

From equations (3) and (4) and the information displayed in Appendix II the reliability of this entire test was calculated to be $r_M = .9024$. Category I students were chosen as a reliability base for the following reasons:

1. All data and comparisons are to be based on their performance.

2. Strict time limitations were imposed on these testees and we feel that their test conditions are more in keeping with the stipulations and assumptions made in the development of the reliability equations.[4]

In the final analysis, validity has to do with what test scores measure and what they will predict. A score is valid for predicting anything with which it correlates, where "anything" does not include the score itself, for a self prediction has to do with reliability.[5] We chose to predict

[4]Guilford, J. P. Psychometric Methods, McGraw Hill Co., Inc., New York, 1954: 366

[5]Ibid: 398

final graduate level QUALITY POINT RATING* of Operations Analysis graduates of USNPGS. Here we have assumed that the degree of successful completion of the curriculum (hence a measure of technical ability) is measured by the reliability of the criterion of Q.P.R.; although the reliability of Q.P.R. as a criterion is not known, it is the only quantitative measure we have for comparison and have therefore assumed, for the purposed of this study, it to be 1.0. The results of a multiple linear regression analysis (Appendix IV, pp.50) shows that the correlation coefficient of Q.P.R. to various parts of the test scores is a minimum of .5978 and a maximum of .6142. As shown in Appendix IV, it was found that Part II versus Time in Operations Analyst billet or Time since Graduation, Part I and Category type had a multiple correlation of .8210, indicating that technical knowledge is extremely dependent upon inherent ability and the way time is utilized after aquisition of these abilities. Since the reliability of this test is a high .9024 and its overall correlation to a real life criterion is high, it follows that the quantitative adequacy of this test is very high.

* Hereafter referred to as Q.P.R., with a maximum of 3.0.

Within the assumptions stated, the quantitative reliability and validity calculation and the previous subjective verifications, the overall adequacy of this test is excellent.

One final word on this "sticky" subject. This test was sent to Mr. R.P. Richardson, Head Operations Analyst for LING-TEMPCO-VAUGHT ASTRONAUTICS in Dallas, Texas for his comment as well as the reaction of his fellow employees. Mr. Richardson replied that in his opinion, and the opinion of his collegues, the overall design of the test should yield a <u>practical</u> <u>relative</u> measure of the technical tools of Operations Analysts.

II. Comments on the suggested method and proposed measure of effecticeness.

In the suggested methodology, two families of curves were to be plotted and studied in hopes of arriving at a useful measure of effectiveness. The first family of curves was to be a plot of weighted adjusted score (as described in I above) for categories 2A, 2B, 2C versus time. The courses were postulated to appear as in Figure 2.

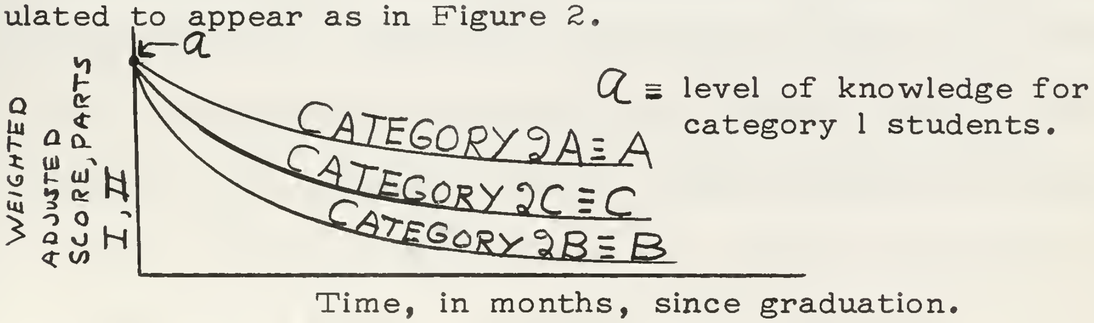
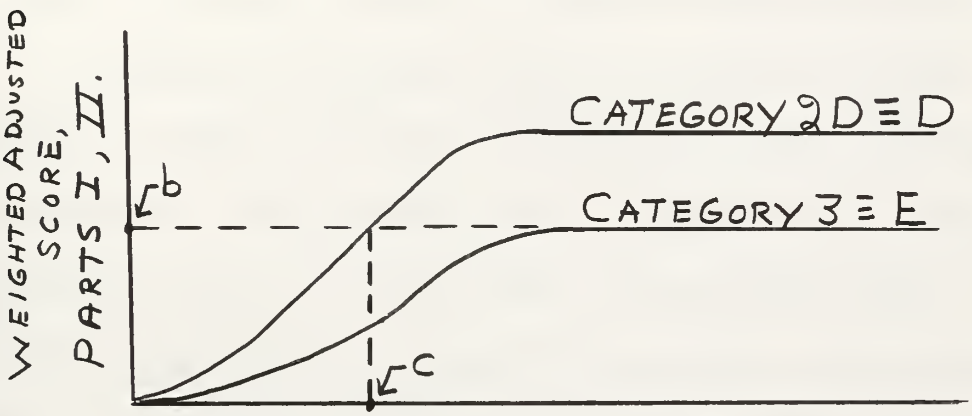


FIGURE 2

The second family of courses were to be concerned with the process of learning and relearning basic technological knowledge and were hypothesized to appear as in Figure 3.



Time, in months, in Operations Analyst billet.

FIGURE 3

The plots of Figure 2, if correct, would indicate that intervening duty assignments between acquisition of technical knowledge and application in the given field results in a larger loss of the tools required. A useful M.O.E. was to be constructed from the type graphs of figure 3. For example: if "b" in figure 3 indicates the ordinal value of the asymptote of curve E, the ratio of curriculum time to curriculum time plus time required for category 2D (graduates who are essentially re-learning the technical tools) would yield a value between 0 and 1, a higher value correlating to a more effective utilization of the technical resorurce and would imply a certain percentage of effectiveness. If this

ratio were to be drastically low it would demonstrate the need for assigning the technically trained to associated billets immediately after graduation to more effectively utilize the costly process of educating these individuals.

Appendix III contains plots of weighted adjusted scores on Part II versus Time for the above mentioned categories. These graphs have the approximate shapes of Figures 2 and 3. At this point this particular plan of attack breaks down. As previously stated, 34 returns out of a population of 197 was realized. This resulted in a maximum of 14 points for the learning curve for category 3 and a minimum of two points for category 2C. It is a well known fact that little credence can be placed in a statistical procedure unless:

I. The sample size is very large (.9 to .95) in proportion to the population size, or[6]

II. One can safely assume knowledge of the exact distribution of the random variables observed, and/or have control over the method of selecting the sample size.[7]

[6] Burington, R. S., and May, D. C. Handbook of Probability and Statistics with Tables, Handbook Publishers, Inc., Sandusky, Ohio 1953: 170

[7] Ibid: 170-178

Clearly none of these proposed curves contain data satisfying any of these conditions. At most, one can say that the data so far gathered crudely support the hypothesized curves and that future study along these lines has more than a possibility of being fruitful.

If, however, we consider the sample size to consist of only two groups, Operations Analysis graduates and Non-Operations Analysis graduates, several meaningful implications can be garnered from the test results. (Group I Operations Analysis Graduates, Group II Non-Operations Analysis Graduates). The mean score on Part I for Group II was 6.0 points below Group I indicating a significantly lower proficiency in the area of problem solving. The mean scores on Parts II and III were respectively, 3 and 4 times as high for Group I as for Group II. These mean scores had a standard deviation of less than 7.0 for the "worst" case. Group I's comments on the courses that they thought they were lacking were of a highly specialized nature (Dynamic Programming, Specialized Methods of Cost-Effectiveness, etc.) while Group II's overall response indicated they were lacking in the most rudimentary areas such as basic probability and statistics, linear programming, calculus, etc. Only two officers in Group II had any postgraduate education.

These disparities in relative performance of Group II to Group I exist despite the fact that the mean time in billet for Group II is 19 months - only two months less than time required for completion of the Operations Analysis Curriculum, thus indicating that on-the-job training is not very effective. From these facts there exists a clear implication that there is a significant difference in the technical abilities and therefore effectiveness of Group I and Group II as practicing Operations Analysts. The least one could say is that Group I displays a marked advantage over Group II in the technical tools needed in the field of Operations Analysis.

One might say this is not surprising - any logical person would safely assume an Operations Analysis trained person to be more effective than one not so trained. This conjecture is most likely true in highly specialized fields (such as microelectronics), but cannot be safely assumed for fields such as Operations Analysis. Operations Analysis is concerned with optimal solutions to real life problems arrived at by the applications of all sciences and the rational logic intrinsic to them. Therefore it could just as well be said that an officer with a good working knowledge of "the sciences" has an excellent chance of being an effective

Operations Analyst. Although all examinees in Group II have Bachelor's degrees in fields requiring the basic mathematical and scientific technologies used by the Operations Analyst, the quantitative results of this study indicate that their ability to effectively apply these tools to Operations Analysis problems is relatively low.

Why is all this important? The Navy has stated that its policy in the future will be to continue to educate officers at the Postgraduate level in ever-increasing numbers.[8] Whatever their reasons may be for arriving at this decision, the cost of training these officers has or will be expended and cannot be recovered. It therefore logically follows that the most effective use of these officers will yield the maximum return for the money spent. In the past, many Operations Analysis trained officers have never held Operations Analyst billets and many officers have been assigned to these billets so long after their training as to nullify the maximum effectiveness they could display.[9] It is highly likely that this situation exists in other technical fields within the Navy.

[8] OPNAV Instruction 1040.2 dated 9 December 1963: 2

[9] Roman, P. D., Russel, K. B., and Dunlop, J. M. A Suggested Method for Measuring the Effectiveness of the Utilization of Technically Trained Personnel, U.S. Naval Postgraduate School, Monterey, California 1964: 9

These results clearly indicate that the Navy should give more thought to the problem of using the technical abilities of these officers more effectively. Specifically, a review of present career planning should be made in hopes of arriving at a method of duty assignment planning which will allow technically trained officers to be assigned associated billets compatible with their education at the earliest possible date after completion of this education. This of course must be done in light of providing the officer with the operational experience necessary for Military Command.[10] The authors are certain that the Navy is aware of this problem, but may not be cognizant of the fact that the use of officers not trained in such specialties as Operations Analysis results in a large loss of effectiveness that could be realized by more judicious use of the available corps of technically trained officers.

[10]SECNAV Instruction 1520.4 dated 7 March 1963: 2

III. Prediction of performance in Operations Analysis Training.

During the gathering and analysis of the data for the previous parts of this paper the authors discovered what appeared to be another fruitful avenue of investigation; the prediction of performance in the Operations Analysis Curriculum. Since Q.P.R. is accepted universally as a measure of a person's knowledge of the technical tools acquired during his training, it would be especially welcome if some means of predicting, before training commenced, the approximate skill any particular person, or more appropriately, any group of persons would aquire. If such a predictor could be developed, any input group to the Operations Analysis Curriculum could be selected so as to yield maximum benefit to the Navy for the time and money expended on the training.

In an attempt to develop some prediction relationships, a number of statistics were considered as variables. Using Q.P.R. as the variable to be predicted nine other statistics were treated as the predictors;

1. Score on Part I of the test vehicle.
2. Verbal score on the Graduate Record Examination.
3. Quantitative score on the Graduate Record Examination.

4. Advanced score on the Graduate Record Examination.

5. Time since graduation or time in an Operations Anslysis billet.

6. Score Part II of the test vehicle.

7. Score Part III of the test vehicle.

8. Category as defined previously for responders.

9. Sum of Parts I, II, and III.

A standard linear regression analysis (see Appendix IV) was performed on a CDC 1604 to obtain the prediction equations. The level of significance on the F-test used was fixed at 0.01 for all runs. As previously mentioned in Part II of this paper one run was made using the scores of Part II and then Part III of the test vehicle as the dependent variable. Many other equations were also obtained, not with the purpose of predicting Q.P.R. specifically but for obtaining as much information about the correlations of the various statistics as possible. A complete summary of these equations is contained in Appendix IV. Initially three different groups of data points were used:

I. All Operations Analysis students and graduates for which Q.P.R., and the G.R.E. scores were available.

II. The class of 1965.

III. The class of 1965 and previous Operations Analysis graduates whose statistics were available.

From each group of data points eight regression equations were obtained. All these equations are tabulated in Appendix IV. The equations of interest in predicting Q.P.R. are necessarily those containing only independent variables which are readily available before a person or person's start the course of instruction. Of the group of variables used in the analysis only Part I and the G.R.E. scores would be obtainable prior to enrolement.

The following is the regression analysis and equations obtained in the order of the groups of data points.

GROUP I

Variable No.	Mean	Standard Deviation	Regression Coefficient	Std. Error of Reg. Coef.
2	50.318	6.349	.031	.011
3	579.649	108.514	.001	.001
4	673.377	86.551	.001	.001
5	308.701	248.352	.000	.000
1	1.938	.625		

Multiple Correlation Coefficient .5978

Computed T Value	Partial Corr. Coef.	Variance Added	Prop. Var. Cum.
2.778	.311	7.670	.259
1.466	.170	1.672	.056
1.639	.189	.699	.024
1.446	.168	.553	.019

GROUP II

Variable No.	Mean	Standard Deviation	Regression Coefficient	Std. Error of Reg. Coef.
2	52.228	5.365	.032	.013
3	610.833	76.322	-.001	.001
4	675.556	95.900	.001	.001
5	545.000	91.853	.001	.001
1	2.043	.410		

Multiple Correlation Coefficient .6142

Computed T Value	Partial Corr. Coef.	Variance Added	Prop. Var. Cum.
2.483	.407	1.747	.296
-.993	-.176	.037	.006
.662	.118	.147	.025
1.571	.272	.292	.050

GROUP III

Variable No.	Mean	Standard Deviation	Regression Coefficient	Std. Error of Reg. Coef.
2	52.433	6.017	.022	.010
3	607.111	82.754	-.001	.001
4	682.889	91.617	.001	.001
5	554.444	93.628	.002	.001
1	2.103	.413		

Multiple Correlation Coefficient .6118

Computed T Value	Partial Corr. Coef.	Variance Added	Prop. Var. Cum.
2.289	.340	1.652	.220
- .943	-.148	.003	.000
.773	.121	.292	.039
2.712	.394	.864	.115

It is readily seen from the above equations that the multiple correlation coefficients of the three groups of data points are remarkably constant (0.5978, 0.6142, 0.6118). The authors found this somewhat surprising since previous analysis of data had indicated that the Q.P.R. of the 1966 class would not have settled down into the same pattern as those of the 1965 class and the graduates. It had further been hypothesized that the data points obtained from graduates would be somewhat distorted due to their high mean Q.P.R. and the fact that since they were not in school they would have lost some of their "test taking ability." Even though the multiple correlation coefficients are fairly constant over the three groups of data it is apparent that the class of 1966 does degrade the results and it is therefore felt that either the second or third equation should be used for prediction.

As time passes and more data points are obtained it is felt that this method will yield ever better prediction equations. The authors leave it to the readers to decide if the present equations with approximately 0.34 as the standard error of estimate is sufficiently accurate for their application. The authors do feel that the results

obtained thus far strongly support the hypothesis that the predictors (Part I, G.R.E. scores) can be used to select the makeup of a class or predict the performance of a previously selected group. It is further felt that these predictors and methodology could be applied to other curricula with equally promising results.

CHAPTER III

CONCLUSIONS AND RECOMMENDATIONS

Reliability and Validity determinations for the test instrument have shown that the basic tool of the proposed methodology is a feasible and meaningful model with which to measure technical resources. Admittedly there are a number of necessarily subjective "proofs" included in this analysis, but the authors feel that quantitative determinations have served to augment these "proofs," and provide a creditable coalescence leading to an overall high degree of adequacy for the test vehicle. This logical trajectory had led the authors to the conclusion that this test does measure relative percentages of technical resources which in turn gives an excellent indication of effectiveness in billets requiring these resources.

Analysis of the data garnered from this test model on the Operations Analysis Curriculum has objectively indicated that:

(1) The percentage of technical resources retained decreases logarithmically (approximately) with time.

(2) On-the-job training in Operations Analyst billets is significantly inferior to formal Operations Analysis training -

especially in the area of learning fundamental technical knowledge.

(3) If technical ability is utilized immediately after it's acquisition, loss of this resource occurs at a slower rate.

(4) Although Operations Analysis is a field utilizing mainly the basic sciences (Mathematics, Physics, Probability, etc.), College Graduates (Non Operations Analysis trained) holding degrees which require knowledge of most of these subjects do not possess nor readily learn the basic tools of the Operations Analyst.

(5) Graduates of the Operations Analysis Curriculum (regardless of time since completion of course or use or non-use of technical abilities) display three (3) to four (4) times the technical knowledge of College Graduates who have held Operations Analyst billets for an average of 19 months.

(6) Use of Part I of the test instrument and the three parts of the graduate achievement tests taken by all students of USNPGS has yielded a quantitative method of augmenting the screening of prospective students to the Operations Analysis Curriculum.

From these conclusions it is recommended that:

(1) Further investigation of this methodology be under-

taken. It is obvious that the sample sizes obtained were not large enough to make "bullet proof" statistical conclusions but rather serve as indications that the stated postulates concerning the use of technical abilities and the effectiveness of various groups of officers holding Operations Analyst billets are essentially correct.

(2) The significant disparity in technical abilities of the two groups of officers mentioned in 5. (above) definitely suggests that Naval Officer assignment policies be reviewed in hopes of assigning as many Operations Analysis trained officers to Operations Analyst billets as is consistent with other requirements.

(3) Use of the regression equations and correlation coefficients presented in Appendix IV would be of considerable use for Operations Analysis Curriculum officials in balancing the levels of Operations Analysis Classes in any manner consistent with the ever changing policies and needs of the Postgraduate School.

(4) If future investigations of this type are undertaken a more effective method of insuring the test subjects complete the required questionaire and test instrument should be invoked. The authors were forced to appeal to the examinees sense of responsibility, their response being completely voluntary.

It is felt that in order to obtain meaningful sample sizes from which learning and forgetting curves can be accurately constructed, and measures of effectiveness deduced, completion of the test vehicle should, in some manner, be made mandatory.

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APPENDIX I

SCORES ACHIEVED ON TEST INSTRUMENT

CATEGORY I CLASS 1965

					G.E.D. RESULTS		
Examinee	PART I	PART II	PART III	QPR	VERB	QUAN	ADV
1	53.0	16.5	1.85	1.92	510	570	540
2	49.88	26.5	2.85	2.34	600	570	610
3	49.6	16.5	2.85	1.50	590	640	520
4	52.6	21.5	2.85	2.19	610	690	480
5	60.9	29.5	3.85	2.83	610	740	520
6	51.96	20.5	.855	1.80	630	760	500
7	53.5	15.5	1.85	2.11	730	590	490
8	55.6	32.5	6.85	1.98	520	600	580
9	50.6	17.5	2.85	1.83	570	620	510
10	60.6	27.5	1.85	2.31	590	810	540
11	47.6	11.5	2.85	2.00	590	780	560
12	50.6	21.5	2.85	1.85	680	840	570
13	61.6	35.5	2.85	2.53	600	850	730
14	49.0	19.5	1.85	1.38	510	480	460
15	52.6	27.5	4.85	2.27	710	770	550
16	48.6	22.5	2.85	1.47	660	690	470
17	45.63	26.5	2.85	2.56	650	570	720
18	51.6	14.5	3.85	1.44	640	550	440
19	51.6	24.5	4.85	2.08	560	660	510
20	50.6	21.5	3.85	2.54	610	600	490
21	49.6	14.5	3.85	1.49	710	680	490
22	47.6	13.5	4.85	1.56	600	690	430
23	50.63	14.5	.858	1.58	530	610	520
24	54.6	28.5	2.85	2.39	610	830	700

CATEGORY 1 CLASS 1965 (Continued)

					G.E.D. RESULTS		
Examinee	PART I	PART II	PART III	QPR	VERB	QUAN	ADV
25	47.6	27.5	4.85	1.83	540	670	590
26	42.0	20.5	3.85	2.36	540	630	390
27	60.6	26.5	2.85	2.29	670	690	680
28	53.6	27.5	3.85	2.47	590	720	420
29	47.6	16.5	4.85	1.89	720	760	720
30	60.6	23.5	6.85	2.39	710	780	560
31	63.6	26.5	5.85	2.60	680	840	750
32	50.0	25.5	.858	2.25	440	570	510
33	60.6	25.5	4.85	2.32	760	660	580
34	41.6	14.5	1.85	1.42	530	590	420

	PART I	PART II	PART III	SUM I,II,III	Q.P.R.
Mean	52.08	22.04	3.3	77.40	2.046
Standard Deviation	7.81	5.96	1.42	10.04	

CATEGORY 1A INPUT OPERATIONS ANALYSIS CLASS 1966 - PART ONE TAKEN DURING FIRST TERM IN CURRICULUM

Examinee	PART I
1	50.6
2	52.6
3	35.6
4	45.6
5	54.6
6	50.6
7	53.6
8	45.6
9	33.6
10	47.6
11	51.6
12	54.6
13	49.6
14	60.6
15	38.6
16	38.0
17	44.6
18	47.6
19	43.6
20	46.6
21	53.6
22	51.6
23	37.6
24	43.6
25	50.6
26	46.6
27	58.6
28	44.0
29	52.6
30	50.6
31	48.6
32	49.6
33	54.6
34	41.6

Mean = 47.9

Standard Deviation = 6.41

CATEGORY 2A OPERATIONS ANALYSIS GRADUATES WHO HAVE GONE DIRECTLY TO OPERATIONS ANALYST BILLETS

Examinee	Months time since Graduation	PART I	PART II	PART III	SUM I,II,III	QPR	
1	16	50.9	19.5	2.85	73.35	2.29	
2	16	45.5	15.5	3.95	64.80	2.08	
3	26	53.6	33.5	5.85	92.95	2.93	
4	18	46.3	18.5	3.85	68.65	2.30	
5	4	59.8	31.0	4.85	95.65	3.0	
6	4	41.6	17.5	4.85	63.95	2.14	
7	18	54.4	25.5	3.85	83.75	1.67	1 yr only
8	9	62.6	22.5	2.85	87.95	2.31	
9	18	66.6	31.5	2.85	100.95	2.25	

	PART I	PART II	PART III	SUM I,II,III	QPR
Mean	53.37	23.82	3.96	81.33	2.33
Standard Deviation	7.95	6.64	.96	15.8	

CATEGORY 2B OPERATIONS ANALYSIS GRADUATES WHO HAVE NEVER HELD BILLETS

Examinee	Months time since Graduation	PART I	PART II	PART III	SUM I,II,III	QPR
1	16	52.2	19.5	3.85	75.5	2.59
2	30	52.88	34.5	5.85	93.23	2.69
3	18	50.83	29.0	.858	80.68	2.02
4	6	46.0	13.5	2.85	62.35	2.44
5	6	52.60	30.5	4.85	87.95	2.56
6	18	55.3	21.5	4.85	81.65	2.32
7	6	57.13	25.5	5.85	88.48	2.41

	PART I	PART II	PART III	SUM I,II,III	QPR
Mean	52.42	24.85	4.13	79.5	2.43
Standard Deviation	4.80	6.71	1.67	2.38	

CATEGORY 2C GRADUATES WHO HAVE COMPLETED DIRECT DUTY IN OPERATIONS ANALYST BILLETS AND ARE NOW IN UNASSOCIATED ACTIVITIES

Examinee	Months time since Graduation	Mo's time since left OA billet	PART I	PART II	PART III	SUM I,II,III	QPR
1	55	34	63.6	17.5	2.85	83.95	2.51
2	24	8	53.63	29.5	4.85	87.98	2.01

	PART I	PART II	PART III	SUM I,II,III	QPR
Mean	58.61	23.50	3.85	85.96	2.26
Standard Deviation	4.80	6.00	1.00	2.24	

CATEGORY 2D GRADUATES WHO HAVE COMPLETED AN INTERVENING ASSIGNMENT AND ARE NOW IN OPERATIONS ANALYST BILLETS

Examinee	Months time since Graduation	Months time in OA billet	PART I	PART II	PART III	SUM I,II,III	QPR
1	66	3	57.63	6.5	.857	65.00	2.05
2	34	6	57.00	10.5	4.85	72.35	2.65
3	77	2	52.63	9.5	5.85	67.98	2.69

	PART I	PART II	PART III	SUM I,II,III	QPR
Mean	55.75	8.83	3.85	68.51	2.46
Standard Deviation	1.41	.633	2.16	3.05	

STATISTICS FOR THE 21 OPERATIONS ANALYSIS GRADUATES COMPLETING TEST INSTRUMENT

	PART I	PART II	PART III	SUM I,II,III	QPR
Mean	55.03	21.01	3.94	79.90	2.37
Standard Deviation	8.95	10.9	1.56	12.21	

CATEGORY 3 NON OPERATIONS ANALYSIS GRADUATES HOLDING OPERATIONS ANALYSTS BILLETS

Examinee	Months time in Billet	PART I	PART II	PART III	SUM I, II, III
1	14	37.8	.5	-1.14	37.16
2	38	52.2	7.5	.857	60.55
3	22	50.1	13.45	.857	64.42
4	18	48.63	4.5	-.142	51.71
5	18	56.63	10.5	.857	68.00
6	34	59.6	26.5	-1.14	84.96
7	14	47.6	-1.	-.142	46.45
8	6	53.9	.5	-1.14	53.26
9	8	56.73	1.5	-1.14	57.09
10	18	48.60	22.5	1.85	72.95
11	9	50.60	1.	-1.14	50.46
12	30	53.60	5.5	1.85	60.95
13	18	32.60	6.5	.857	39.97

	PART I	PART II	PART III	SUM I, II, III	TIME
Mean	49.88	7.65	-.460	57.53	19
Standard Deviation	7.21	7.5	.714	7.94	4.58

APPENDIX II

RELIABILITY DATA

RELIABILITY DATA - OPERATIONS ANALYSIS CLASS 1965

STUDENT	I odd item score $\equiv O_i$	II even item score $\equiv E_i$	III $(x_i - \bar{x})^2$	IV total test score $\equiv t_i$	V $(t_i - \bar{t})^2$	VI test error score $\equiv t_{ei}$	VII $(t_{ei} - \bar{t}_{ei})^2$	VIII number of unattempted items $\equiv u_i$	IX $(u_i - \bar{u})^2$	X number of items answered incorrectly $\equiv w_i$	XI $(w_i - \bar{w})^2$
1	36.25	36.70	4.62	71.35	16.0	34.65	13.32	5	.0528	52	52.27
2	37.45	39.50	.175	76.95	25.0	40.05	3.06	7	4.97	43	3.13
3	39.45	37.80	.423	77.25	.30	39.75	2.10	2	7.68	42	7.67
4	36.71	38.27	.739	74.98	.025	42.02	13.69	5	.0528	48	10.43
5	35.28	38.03	.202	73.31	5.85	43.69	29.05	6	1.51	46	1.51
6	37.16	28.82	37.72	65.98	9.00	41.02	9.0	4	.59	54	85.19
7	34.61	34.62	5.29	79.23	129.9	37.77	.018	5	.0528	46	1.51
8	42.62	47.33	5.81	89.95	3.34	27.05	127.69	3	3.13	34	115.99
9	37.16	33.79	1.00	70.95	157.50	46.05	60.06	6	1.51	51	38.81
10	29.00	22.95	14.26	51.95	42.93	65.05	280.56	7	4.97	63	328.69
11	44.32	46.63	.001	90.95	647.70	26.05	297.56	3	3.13	42	7.67
12	45.63	39.32	4.001	84.95	57.00	32.05	27.56	2	7.66	41	14.21
13	37.41	38.54	1.54	75.95	2.01	41.05	7.56	0	22.71	48	10.43
14	33.57	34.38	1.76	67.95	89.30	50.08	138.76	4	.59	53	67.73
15	31.06	35.29	3.72	66.35	121.00	50.65	152.52	16	126.50	50	27.35
16	38.04	36.91	1.54	74.95	6.00	42.05	14.06	6	1.51	47	4.97
17	46.69	42.66	5.15	85.35	63.20	31.65	58.52	3	3.13	38	45.83
18	43.71	42.24	3.34	95.95	344.41	21.05	297.56	2	7.68	33	138.53
19	45.95	44.00	.136	99.95	464.40	17.05	451.56	0	22.71	28	281.23
20	44.21	46.14	.138	90.35	167.70	26.65	135.72	0	22.71	36	163.07
21	41.34	44.61	.756	85.95	57.00	31.05	52.56	4	.59	38	45.83

STUDENT	I odd item score $\equiv O_i$	II even item score $\equiv E_i$	III $(x_i - \bar{x})^2$	IV total test score $\equiv t_i$	V $(t_i - \bar{t})^2$	VI test error score $\equiv t_{ei}$	VII $(t_{ei} - \bar{t}_e)^2$	VIII number of unattempted items $\equiv u_i$	IX $(u_i - \bar{u})^2$	X number of items answered incorrectly $\equiv W_i$	XI $(W_i - \bar{W})^2$
22	37.89	35.06	.28	72.95	19.80	44.05	33.06	4	.59	44	.592
23	21.80	26.05	.342	57.85	382.20	59.15	430.56	8	10.41	52	52.27
24	35.33	34.62	2.52	69.95	55.50	47.05	76.56	6	1.51	47	4.97
25	49.60	45.35	3.80	94.95	273.39	22.05	264.06	9	17.85	23	473.93
26	40.62	41.33	2.52	81.95	20.70	35.05	10.56	4	.59	43	3.13
27	35.62	34.33	1.00	69.95	55.50	47.05	76.56	4	.59	55	104.65
28	30.66	30.69	5.15	61.35	254.40	55.65	301.02	5	.0528	52	52.27
29	36.71	34.24	.289	70.35	41.60	46.05	60.06	9	17.85	54	85.19
30	32.29	37.66	9.42	79.95	6.50	37.05	1.56	5	.0528	39	33.29
31	35.54	34.81	2.46	70.35	49.70	46.65	69.72	2	7.68	46	1.51
32	33.74	32.61	1.54	66.35	122.10	50.65	152.52	3	3.13	54	85.19
33	38.69	37.71	1.74	76.40	1.0	40.60	5.29	2	7.68	44	.592
34	34.84	34.21	2.78	69.05	54.02	47.95	93.12	10	27.40	53	67.73
35	44.81	48.24	1.27	91.05	186.32	25.95	152.52	5	.0528	36	76.91
36	46.21	44.31	.16	90.52	172.13	26.48	139.97	6	1.51	37	60.37

IN COLUMN III, $x_i = O_i - E_i$.

$\bar{x} = \frac{1}{36} \sum x_i$ $\quad \bar{t} = 77.40$ $\quad \bar{t}_e = 38.30$ $\quad \bar{u} = 4.77$ $\quad \bar{W} = 44.77$

$\bar{x} = 2.30$ $\quad \sigma_t^2 = 100.976$ $\quad \sigma_{te}^2 = 112.211$ $\quad \sigma_u = 5.69$ $\quad \sigma_W^2 = 70.931$

$\sigma_d^2 = \frac{1}{36} \sum III_i$

$\sigma_d^2 = 3.52$

RELIABILITY CALCULATIONS

Data from Table #1

Equations from Chapter II

$R_M \equiv$ RELIABILITY FOR TEST INSTRUMENT.

$$R_M = \left[1 - \frac{\sigma_d^2}{\sigma_t^2}\right] - \frac{\bar{U}}{\sigma_{te}^2},$$

PROVIDED: $\frac{\bar{U}}{\sigma_{te}^2} \leq 0.3$ AND $\frac{\sigma_u}{\sigma_w} \leq 1.3$.

$$\Rightarrow R_M = \left[1 - \frac{3.52}{100.976}\right] - \left[\frac{4.77}{112.211}\right].$$

$$R_M = 0.9024.$$

$$\frac{\bar{U}}{\sigma_{te}^2} = \frac{4.77}{112.211} = 0.0466 < 0.3.$$

$$\frac{\sigma_u}{\sigma_w} = \frac{2.38}{8.43} = 0.282 < 1.3.$$

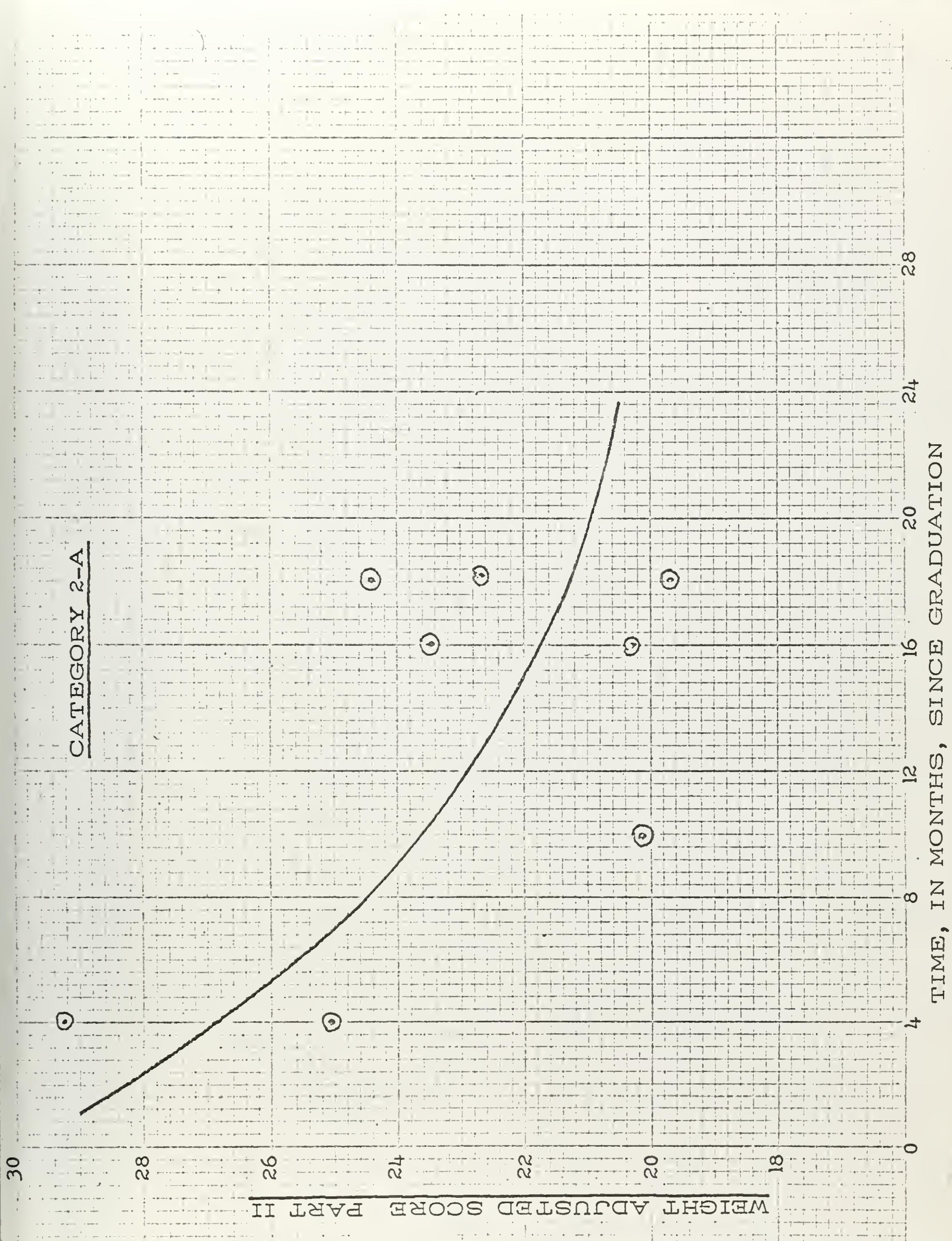
Q.E.D.

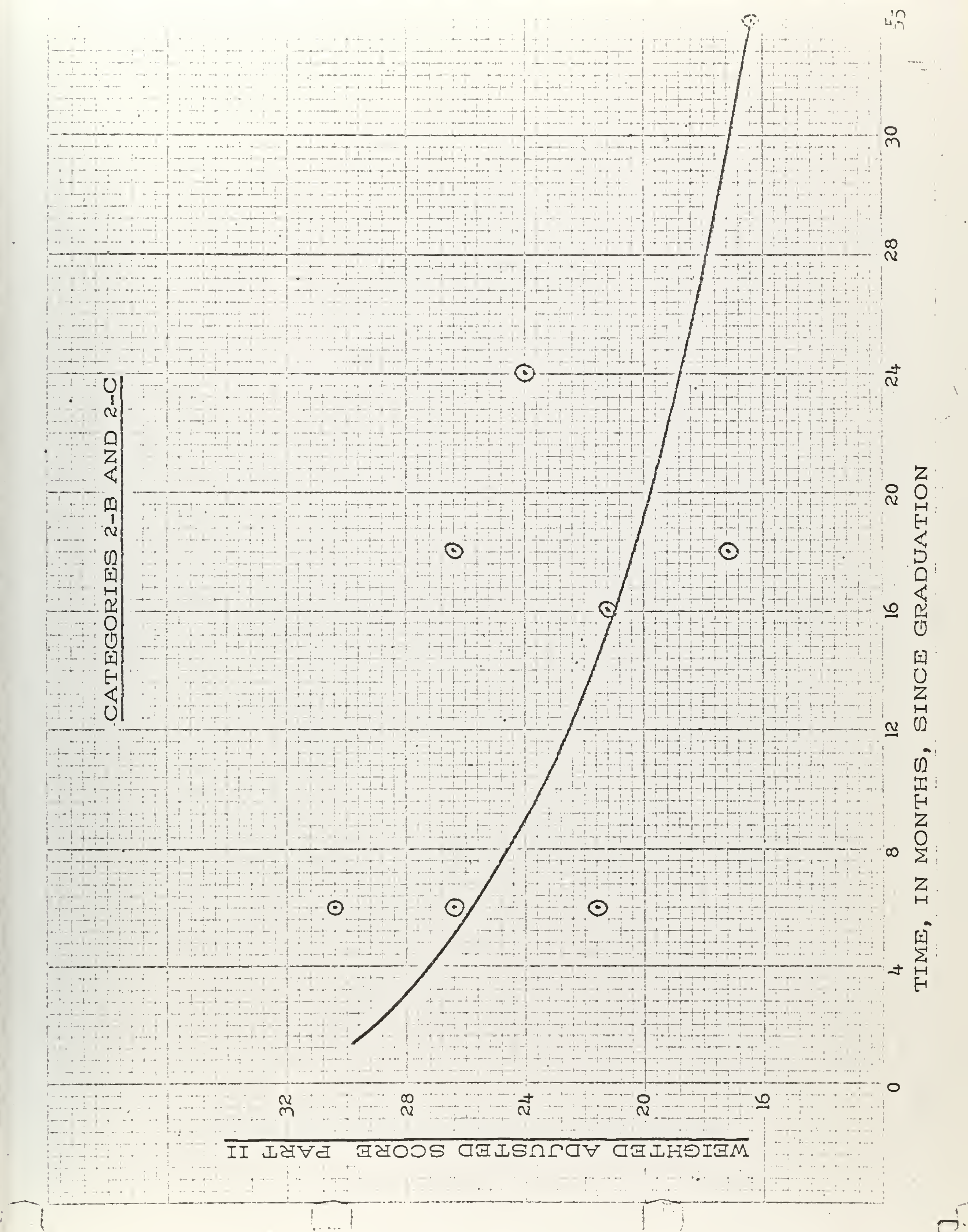
APPENDIX III

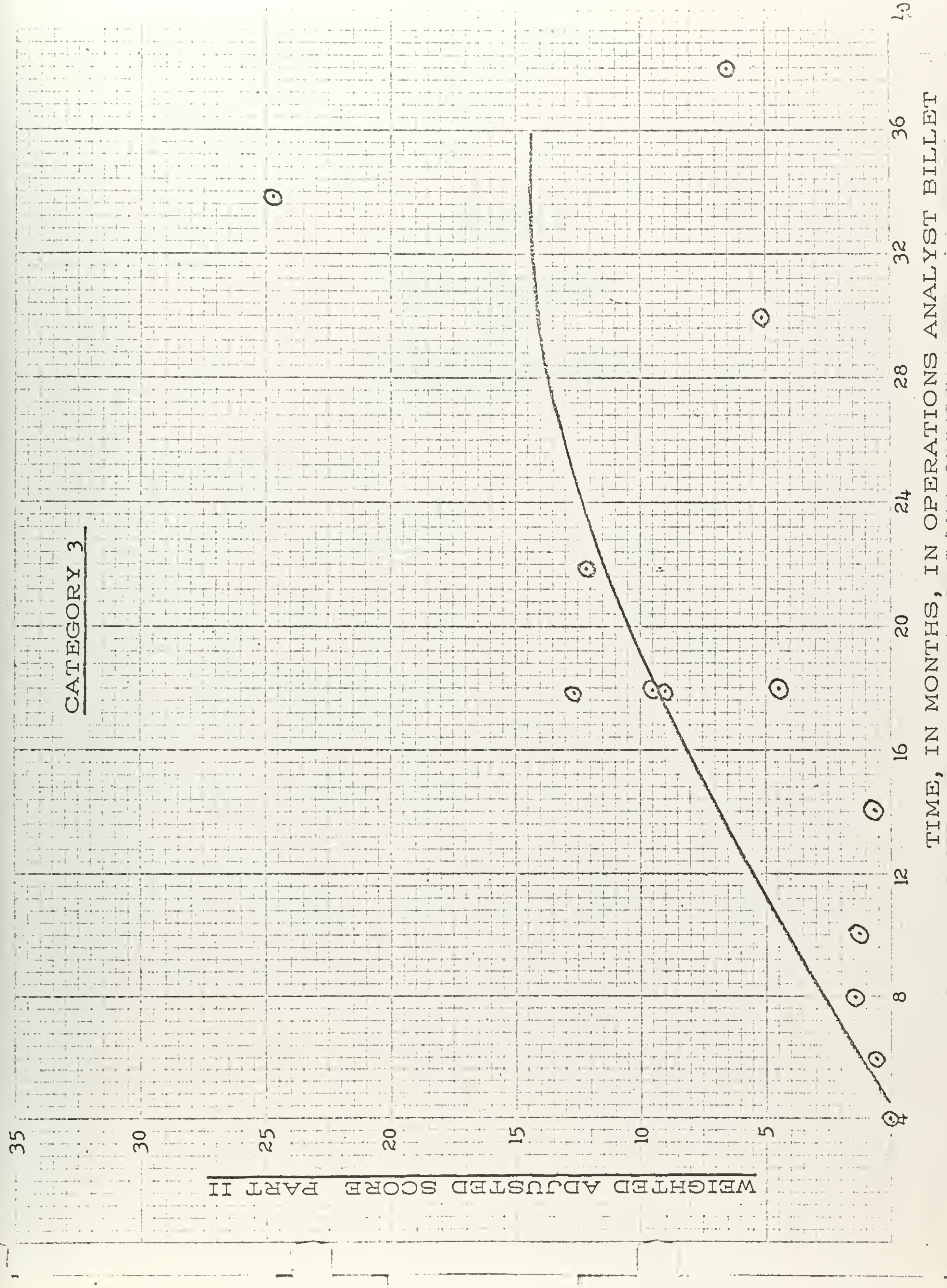
Learning, Relearning and Forgetting Curves

KEY TO GRAPHS

Weighted Adjusted Score is the ratio of the Mean Score of a particular category to the individual's score on Part I multiplied by the individual's score on Part II.


CATEGORY 2-A
WEIGHT ADJUSTED SCORE PART II
TIME, IN MONTHS, SINCE GRADUATION
30
28
26
24
22
20
18
0
4
8
12
16
20
24
28


CATEGORIES 2-B AND 2-C
WEIGHTED ADJUSTED SCORE PART II
32
28
24
20
16
TIME, IN MONTHS, SINCE GRADUATION
0
4
8
12
16
20
24
28
30


CATEGORY 3
WEIGHTED ADJUSTED SCORE PART II
35
30
25
20
15
10
5
4
8
12
16
20
24
28
32
36
TIME, IN MONTHS, IN OPERATIONS ANALYST BILLET

APPENDIX IV

REGRESSION EQUATIONS

AND

CORRELATION COEFFICIENTS

GROUP I

Regression Equations using all Operations Analysis students and graduates for which QPR, and the G.R.E. scores were available.

Variable No.	
1	Quality Point Rating
2	Part I Score
3	G.R.E. Verbal Score
4	G.R.E. Quantitative Score
5	G.R.E. Advanced Score
6	Time (in billet or out of school)
7	Part II Score
8	Part III Score

CORRELATION COEFFICIENTS

ROW 1	1.00000	.42051	.39584	.37374	.50869
ROW 2	.42051	1.00000	.47756	.30214	.42939
ROW 3	.39584	.47756	1.00000	.19532	.41359
ROW 4	.37374	.30214	.19532	1.00000	.35157
ROW 5	.50869	.42939	.41359	.35157	1.00000

SAMPLE SIZE 77
NO. OF VARIABLES 5 NO. OF VARIABLES DELETED 3 (FOR VARIABLES
DEPENDENT VARIABLE IS NO NO. 1 DELETED, SEE BELOW)

COEFFICIENT OF DETERMINATION .3574
MULTIPLE CORR. COEFFICIENT .5978

SUM OF SQUARES ATTRIBUTABLE TO REGRESSION 10.59485
SUM OF SQUARES OF DEVIATION FROM REGRESSION 19.04868

VARIANCE OF ESTIMATE .26456
STD. ERROR OF ESTIMATE .51436

INTERCEPT (A VALUE) -1.14097
STD. ERROR OF INTERCEPT .57577

ANALYSIS OF VARIANCE FOR THE MULTIPLE LINEAR REGRESSION

SOURCE OF VARIATION	D.F.	SUM OF SQUARES	MEAN SQUARES	F VALUE
DUE TO REGRESSION	4	10.59485	2.64871	10.0116
DEVIATION ABOUT REGRESSION	72	19.04868	.26456	
TOTAL	76	29.64352		

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	50.31818	6.34913	.03057	.01100	2.77835	.31118	7.67059	.25876
3	579.64935	108.51386	.00096	.00065	1.46554	.17020	1.67211	.05641
4	673.37662	86.55103	.00131	.00080	1.63882	.18963	.69872	.02357
5	308.70130	284.35222	.00033	.00023	1.44632	.16803	.55343	.01867
1	1.93779	.62454						

COMP. CHECK ON FINAL COEFF. .00033

MEASURE OF EFFICIENCY (STD. ERROR OF EST./REG. COEFF.)
16.82825 535.97354 392.20669 1565.91004

VARIABLES DELETED 6 7 8

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	50.31818	6.34913	.04322	.01054	4.10178	.43522	7.67059	.25876
6	1.27273	4.22909	.01592	.01520	1.04719	.12248	.59153	.01995
7	12.36364	11.87175	.01039	.01010	1.02826	.12030	.82547	.02785
8	1.93506	2.02699	-.00489	.06015	-.08132	-.00958	.00189	.00006
1	1.93779	.62454						

MULTIPLE CORR. COEFFICIENT .5537

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	50.31818	6.34913	.04208	.01049	4.01231	.42507	7.67059	.25876
7	12.36364	11.87175	.00964	.01008	.95571	.11116	1.09873	.03706
8	1.93506	2.02699	.00924	.05865	.15759	.01844	.00710	.00024
1	1.93779	.62454						

MULTIPLE CORR. COEFFICIENT .5441

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
7	12.36364	11.87175	.01538	.01095	1.40416	.16110	4.10546	.13849
8	1.93506	2.02699	.02875	.06414	.44829	.05204	.06917	.00233
1	1.93779	.62454						

MULTIPLE CORR. COEFFICIENT .3753

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
3	579.64935	108.51386	.00141	.00067	2.09168	.23934	5.46559	.18438
4	673.37662	86.55103	.00180	.00082	2.19973	.25095	1.66983	.05633
5	308.70130	284.35222	.00047	.00024	1.96937	.22608	1.41719	.04781
6	1.27273	4.22909	.00819	.01532	.53467	.06289	.08341	.00281
1	1.93779	.62454						

MULTIPLE CORR. COEFFICIENT .5397

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
3	579.64935	108.51386	.00137	.00067	2.05674	.23404	5.46559	.18438
4	673.37662	86.55103	.00184	.00081	2.26467	.25621	1.66983	.05633
5	308.70130	284.35222	.00050	.00023	2.21477	.25093	1.41719	.04781
1	1.93779	.62454						

MULTIPLE CORR. COEFFICIENT .5371

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
6	1.27273	4.22909	.02068	.01688	1.22511	.14007	.58158	.01962
1	1.93779	.62454						

MULTIPLE CORR. COEFFICIENT .1401

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	50.31818	6.34913	.05004	.00978	5.11683	.50869	7.67059	.25876
1	1.93779							

MULTIPLE CORR. COEFFICIENT .5087

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
1	1.93779	.62454	-.06930	.23724	-.29209	-.03514	36.82666	.11794
2	50.31818	6.34913	.00769	.02314	.33246	.03999	15.46977	.04954
3	579.64935	108.51386	.00150	.00134	1.12206	.13386	5.79699	.01856
4	673.37662	86.55103	.00013	.00162	.08047	.00969	.11665	.00037
5	308.70130	284.35222	.00283	.00133	2.12106	.24741	176.21809	.56433
6	1.27273	4.22909	.03930	.02999	1.31047	.15583	.62502	.00200
7	12.36364	11.87175	.07551	.03127	2.41496	.27917	6.01712	.01927
8	1.93506	2.02699						

MULTIPLE CORR. COEFFICIENT .8786

GROUP II

Regression Equations using just the class of 1965.

Variable No.	
1	Quality Point Rating
2	Part I Score
3	G.R.E. Verbal Score
4	G.R.E. Quantitative Score
5	G.R.E. Advanced Score
6	Time (in billet out of school)
7	Part II Score
8	Part III Score

CORRELATION COEFFICIENTS

ROW 1	1.00000	.31319	.49274	.43350	.54445
ROW 2	.31319	1.00000	.43538	.26674	.09552
ROW 3	.49274	.43538	1.00000	.44631	.37425
ROW 4	.43350	.26674	.44631	1.00000	.45348
ROW 5	.54445	.09552	.37425	.45348	1.00000

SAMPLE SIZE 36
NO. OF VARIABLES 5 NO. OF VARIABLES DELETED 3 (FOR VARIABLES DELETED, SEE BELOW)
DEPENDENT VARIABLE IS NOW NO. 1

COEFFICIENT OF DETERMINATION .3772
MULTIPLE CORR. COEFFICIENT .6142

SUM OF SQUARES ATTRIBUTABLE TO REGRESSION 2.22289
SUM OF SQUARES OF DEVIATION FROM REGRESSION 3.66991

VARIANCE OF ESTIMATE .11838
STD. ERROR OF ESTIMATE .34407

INTERCEPT (A VALUE) -.10242
STD. ERROR OF INTERCEPT .64905

ANALYSIS OF VARIANCE FOR THE MULTIPLE LINEAR REGRESSION

SOURCE OF VARIATION	D.F.	SUM OF SQUARES	MEAN SQUARES	F VALUE
DUE TO REGRESSION	4	2.22289	.55572	4.6942
DEVIATION ABOUT REGRESSION	31	3.66991	.11838	
TOTAL	35	5.89280		

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP, VAR. CUM.
2	52.22778	5.36500	.03235	.01303	2.48306	.40730	1.74679	.29643
3	610.83333	76.32169	-.00085	.00085	-.99283	-.17555	.03674	.00624
4	675.55556	95.90008	.00051	.00077	.66220	.11810	.14723	.02498
5	545.00000	91.85392	.00116	.00074	1.57085	.27153	.29212	.04957
1	2.04333	.41032						

COMP. CHECK ON FINAL COEFF. .00116

MEASURE OF EFFICIENCY (STD. OF EST./REG. COEFF.)
10.63648 -405.47361 676.35531 297.19802

VARIABLES DELETED 6 7 8

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T. VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
1	2.09978	.41395	.35546	.66542	.53419	.08748	8.72377	.10111
2	52.47778	5.98824	.00718	.04171	.17222	.02830	1.24714	.01445
3	609.55556	84.15234	.00478	.00290	1.65107	.26196	4.74970	.05505
4	682.66667	91.61183	.00001	.00286	.00502	.00082	.27828	.00323
5	552.66667	89.22393	.00018	.00288	.06200	.01019	.43616	.00506
6	2.31111	5.39285	.03904	.04048	.96444	.15660	.62575	.00725
7	22.15556	5.90245	.06516	.04462	1.46038	.23345	3.82688	.04435
8	3.50444	1.40032						

MULTIPLE CORR. COEFFICIENT .4801

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T. VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.47778	5.98824	.02829	.01028	2.75334	.39503	1.63794	.21725
3	609.55556	84.15234	-.00079	.00075	-1.05687	-.16285	.02772	.00368
4	682.66667	91.61183	.00119	.00072	1.65533	.25029	.36797	.04881
1	2.09978	.41395						

MULTIPLE CORR. COEFFICIENT .5194

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.47778	5.98824	.02035	.00994	2.04706	.30794	1.63794	.21725
3	609.55556	84.15234	-.00035	.00071	-.49246	-.07763	.02772	.00368
4	682.66667	91.61183	.00074	.00068	1.08038	.16838	.16797	.04881
7	22.15556	5.90245	.02664	.00956	2.78518	.40303	.89432	.11862
1	2.09978	.41395						

MULTIPLE CORR. COEFFICIENT .6232

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.47778	5.98824	.01992	.00998	1.99589	.30443	1.63794	.21725
3	609.55556	84.15234	-.00050	.00074	-.67662	-.10771	.02772	.00368
4	682.66667	91.61183	.00071	.00069	1.02741	.16234	.36797	.04881
7	22.15556	5.90245	.02419	.01000	2.41894	.36119	.89432	.11862
8	3.50444	1.40032	.03532	.04089	.86376	.13701	.08657	.01148
1	2.09978	.41395						

MULTIPLE CORR. COEFFICIENT .6323

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.47778	5.98824	.02262	.00898	2.51854	.36223	1.63794	.21725
7	22.15556	5.90245	.02913	.00911	3.19723	.44243	1.15521	.15322
1	2.09978	.41395						

MULTIPLE CORR. COEFFICIENT .6087

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.47778	5.98824	.02057	.00970	2.12193	.32938	1.63794	.21725
3	609.55556	84.15234	-.00036	.00074	-.49263	-.08072	.02772	.00368
4	682.66667	91.61183	.00023	.00070	.33115	.05436	.36797	.04881
5	552.66667	89.22393	.00100	.00069	1.45400	.23249	.77104	.10227
6	2.31111	5.39285	.01377	.00983	1.40033	.22434	.12693	.01684
7	22.15556	5.90245	.02170	.01071	2.02516	.31589	.55547	.07367
8	3.50444	1.40032	.02153	.04031	.53419	.08748	.03101	.00411
1	2.09978	.41395						

MULTIPLE CORR. COEFFICIENT .6831

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
1	2.04333	.41032	.31496	.77896	.40433	.06501	6.89233	.08727
2	52.22778	5.36500	-.00302	.06141	-.04921	-.00790	2.02006	.02558
3	610.83333	76.32169	.00774	.00383	2.02089	.33366	5.48641	.06947
4	675.55556	95.90008	-.00094	.00332	-.28446	.04826	.02023	.00026
5	545.00000	91.85392	-.00005	.00328	-.01526	-.00225	.16242	.00206
6	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
7	22.38889	5.86407	.08170	.04227	1.93308	.24869	3.98299	.05043
8	3.38333	1.50219						

MULTIPLE CORR. COEFFICIENT .4876

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.22778	5.36500	.02970	.01440	2.06333	.31010	1.74679	.29643
6	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
7	22.38889	5.86407	.04190	.00999	4.19541	.46812	.97901	.16614
8	3.38333	1.50219	-.14538	.04624	-3.14373	.08170	.02114	.00359
1	2.04333	.41032						

MULTIPLE CORR. COEFFICIENT .6578

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.22778	5.36500	.02166	.01174	1.84517	.31010	1.74679	.29643
7	22.38889	5.86407	.03244	.01083	2.99675	.46812	.97901	.16614
8	3.38333	1.50219	.01748	.03770	.46371	.08170	.02114	.00359
1	2.04333	.41032						

MULTIPLE CORR. COEFFICIENT .6828

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
7	22.38889	5.86407	.04190	.00988	4.24209	.59404	2.35451	.39956
8	3.38333	1.50219	.02852	.03856	.73980	.12773	.05773	.00980
1	2.04333	.41032						

MULTIPLE CORR. COEFFICIENT .6398

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
3	610.83333	76.32169	.00000	.00000	.00000	-.11960	.05377	.00912
4	675.55556	95.90008	.00000	.00000	.00000	.24340	.80463	.13654
5	545.00000	91.85392	.00375	.00000		.35503	.63458	.10769
6	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
1	2.04333	.41032						

MULTIPLE CORR. COEFFICIENT .6167

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
3	610.83333	76.32169	-.00062	.00092	-.68143	-.11960	.05377	.00912
4	675.55556	95.90008	.00111	.00079	1.41957	.24340	.80463	.13654
5	545.00000	91.85392	.00164	.00077	2.14832	.35503	.63458	.10769
1	2.04333	.41032						

MULTIPLE CORR. COEFFICIENT .5033

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.22778	5.36500	.04164	.01100	3.78482	.54445	1.74679	.29643
1	2.04333	.41032						

MULTIPLE CORR. COEFFICIENT .5445

GROUP III

Regression Equations using the class of 1965 and previous Operations Analysis graduates whose statistics were available.

Variable No.	
1	Quality Point Rating
2	Part I Score
3	G.R.E. Verbal Score
4	G.R.E. Quantitative Score
5	G.R.E. Advanced Score
6	Sum of Parts I, II, and III
7	Part II Score
8	Part III Score

CORRELATION COEFFICIENTS

ROW 1
1.00000 .34292 .41106 .36267 .46906

ROW 2
.34292 1.00000 .47445 .28329 .14136

ROW 3
.41106 .47445 1.00000 .41974 .35087

ROW 4
.36267 .28329 .41974 1.00000 .51502

ROW 5
.46906 .14136 .35087 .51502 1.00000

SAMPLE SIZE 45
NO. OF VARIABLES 5 NO. OF VARIABLES DELETED 3 (FOR VARIABLES DELETED, SEE BELOW)
DEPENDENT VARIABLE IS NOW NO. 1

COEFFICIENT OF DETERMINATION .3743
MULTIPLE CORR. COEFFICIENT .6118

SUM OF SQUARES ATTRIBUTABLE TO REGRESSION 2.81137
SUM OF SQUARES OF DEVIATION FROM REGRESSION 4.69891

VARIANCE OF ESTIMATE .11747
STD. ERROR OF ESTIMATE .34274

INTERCEPT (A VALUE) .02897
STD. ERROR OF INTERCEPT .53596

ANALYSIS OF VARIANCE FOR THE MULTIPLE LINEAR REGRESSION

SOURCE OF VARIATION	D.F.	SUM OF SQUARES	MEAN SQUARES	F VALUE
DUE TO REGRESSION	4	2.81137	.70284	5.9830
DEVIATION ABOUT REGRESSION	40	4.69891	.11747	
TOTAL	44	7.51028		

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTILA CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.43333	6.01744	.02246	.00981	2.28882	.34030	1.65241	.22002
3	607.11111	82.75435	-.00068	.00072	-.94318	-.14750	.00323	.00043
4	682.88889	91.61734	.00054	.00070	.77278	.12129	.29151	.03881
5	554.44444	93.62778	.00170	.00063	2.71234	.39414	.86422	.11507
1	2.10267	.41314						

COMP. CHECK ON FINAL COEFF. .00170

MEASURE OF EFFICIENCY (STD. ERROR OF EST./REG. COEFF.)
15.25917 -502.45442 635.08100 201.82783

VARIABLES DELETED 6 7 8

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
1	2.10267	.41314	.45906	.60815	.75484	.12315	7.55111	.08583
2	52.43333	6.01744	-.01482	.03851	-.38476	-.06313	1.06707	.01213
3	607.11111	82.75435	.00244	.00274	.89031	.14482	4.27041	.04854
4	682.88889	91.61734	.00267	.00261	1.02321	.16588	.56988	.00648
5	554.44444	93.62778	-.00057	.00252	-.22693	-.03728	.00070	.00001
6	77.83378	11.79030	.05067	.01649	3.07213	.45028	14.13991	.16072
7	22.13333	5.93372	.05388	.03879	1.38909	.22263	2.99270	.03402
8	3.52778	1.41403						

MULTIPLE CORR. COEFFICIENT .5897

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP.VAR. CUM.
2	52.43333	6.01744	.02167	.00921	2.35207	.34857	1.65241	.22002
6	77.83378	11.79030	-.00209	.00489	-.42652	-.06729	.01037	.00138
7	22.13333	5.93372	.02614	.00967	2.70379	.39309	1.11949	.14906
8	3.52778	1.41403	.03916	.04268	.91744	.14356	.09744	.01297
1	2.10267	.41314						

MULTIPLE CORR. COEFFICIENT .6192

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.43333	6.01744	.02134	.00909	2.34776	.34425	1.65241	.22002
7	22.13333	5.93372	.02697	.00937	2.87904	.41008	1.12978	.15043
8	3.52778	1.41403	.03118	.03798	.82095	.12717	.07646	.01018
1	2.10267	.41314						

MULTIPLE CORR. COEFFICIENT .6170

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
7	22.13333	5.93372	.03349	.00942	3.55592	.48104	2.07402	.27616
8	3.52778	1.41403	.04449	.03952	1.12591	.17117	.15927	.02121
1	2.10267	.41314						

MULTIPLE CORR. COEFFICIENT .5453

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
3	607.11111	82.75435	-.00046	.00078	-.59162	-.09314	.15007	.01998
4	682.88889	91.61734	.00093	.00073	1.27315	.19734	.78062	.10394
5	554.44444	93.62778	.00200	.00065	3.08110	.43796	1.26528	.16847
6	77.93378	11.79030	.00146	.00478	.30647	.04840	.01245	.00166
1	2.10267	.41314						

MULTIPLE CORR. COEFFICEINT .5423

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
3	607.11111	82.75435	-.00041	.00075	-.54499	-.08481	.15007	.01998
4	682.88889	91.61734	.00090	.00072	1.25368	.19214	.78062	.10394
5	554.44444	93.62778	.00201	.00064	3.12437	.43853	1.26528	.16847
1	2.10267	.41314						

MULTIPLE CORR. COEFFICIENT .5407

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
6	77.83378	11.79030	.00068	.00534	.12640	.01927	.00279	.00037
1	2.10267	.41314						

MULTIPLE CORR. COEFFICIENT .0193

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
2	52.43333	6.01744	.03220	.00925	3.48276	.46906	1.65241	.22002
1	2.10267	.41314						

MULTIPLE CORR. COEFFICIENT .4691

GROUP IV

Regression Equations using only returns from graduates of the Operations Analysis Curriculum or officers holding Operations Analyst billets.

Variable No.	
1	Time (in billet or since graduation)
2	Part I Score
3	Part II Score
4	Part III Score
5	Category (2A=1.0, 2B=2, 2C=3, 2D=4, 3=5)

CORRELATION COEFFICIENTS

ROW 1
1.00000 -.08659 .20970 .12543

ROW 2
-.08659 1.00000 -.18069 .36119

ROW 3
.20970 -.18069 1.00000 -.72901

ROW 4
.12543 .36119 -.72901 1.00000

SAMPLE SIZE 34
NO OF VARIABLES 4 NO. OF VARIABLES DELETED 1 (FOR VARIABLES
DEPENDENT VARIABLE IS NOW NO. 3 DELETED, SEE BELOW)

COEFFICIENT OF DETERMINATION .6740
MULTIPLE CORR. COEFFICIENT .8210

SUM OF SQUARES ATTRIBUTABLE TO REGRESSION 2526.80694
SUM OF SQUARES OF DEVIATION FROM REGRESSION 1222.22490

VARIANCE OF ESTIMATE 40.74083
STD. ERROR OF ESTIMATE 6.38285

INTERCEPT (A VALUE) 5.60460
STD. ERROR OF INTERCEPT 9.01661

ANALYSIS OF VARIANCE FOR THE MULTIPLE LINEAR REGRESSION

SOURCE OF VARIATION	D.F.	SUM OF SQUARES	MEAN SQUARES	F VALUE
DUE TO REGRESSION	3	2526.80694	842.26898	20.6738
DEVIATION ABOUT REGRESSION	30	1222.22490	40.74083	
TOTAL	33	3749.03184		

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
1	14.67647	8.93655	.36254	.12732	2.84737	.46125	58.97844	.01573
2	52.52235	7.27225	.37009	.15554	2.37930	.39843	522.85379	.13946
5	3.08824	1.72973	-4.60381	.66631	-6.90943	-.78364	1944.97471	.51879
3	16.14559	10.65866						

COMP. CHECK ON FINAL COEFF. -4.60381

MEASURE OF EFFICIENCY (STD. ERROR OF EST./REG. COEFF.)
17.60597 17.24689 -1.38643

VARIABLES DELETED 4

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
1	14.67647	8.93655	-.01417	.03404	-.41628	-.07578	8.09362	.04236
2	52.52235	7.27225	.01045	.04158	.25128	.04583	4.21443	.02206
5	3.08824	1.72973	.99811	.17812	-5.60372	-.71513	91.41917	.47847
4	2.46138	2.40622						

MULTIPLE CORR. COEFFICIENT .7368

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
1	14.67647	8.93655	.04358	.02226	1.95769	.34166	4.34186	.04397
2	52.52235	7.27225	.02446	.02701	.90567	.16585	2.62804	.02662
3	16.14559	10.65866	-.09455	.02565	-3.68541	-.56477	56.35306	.57075
4	2.46138	2.40622	-.23243	.10798	-2.15240	-.37114	4.87794	.04940
5	3.08824	1.72973						

MULTIPLE CORR. COEFFICIENT .8311

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM
1	14.67647	8.93655	.08831	.19764	.95282	.16868	58.97844	.01573
2	52.52235	7.27225	.54941	.24287	2.26221	.37642	522.85379	.13946
3	16.14559	10.65866						

MULTIPLE CORR. COEFFICIENT .3939

VARIABLE NO.	MEAN	STD. DEVIATION	REG. COEFF.	STD. ERROR OF REG. COE.	COMPUTED T VALUE	PARTIAL CORR. COE.	VARIANCE ADDED	PROP. VAR. CUM.
1	14.67647	8.93655	-.05194	.04695	-1.10625	-.19488	8.09362	.04236
2	52.52235	7.27225	.04933	.05770	.85490	.15177	4.21443	.02206
4	2.46138	2.40622						

MULTIPLE CORR. COEFFICIENT .2538